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(71) Applicant: ADC TELECOMMUNICATIONS, INC. [US/US]; 12501 Whitewater Drive, Minnetonka, MN 55343 (US).

(72) Inventor: FARLOW, Charles, S.; 402 William Lakeshore Drive, Waconia, MN 55387 (US).

(74) Agent: FOGG, David, N.; Fogg Slifer & Polglaze, P.A., P.O. Box 581009, Minneapolis, MN 55458-1009 (US).

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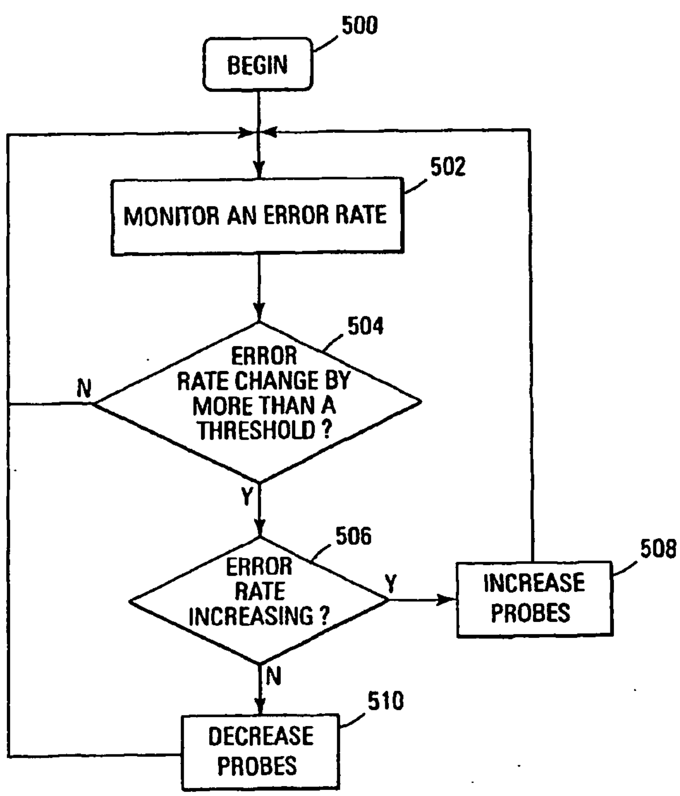
(54) Title: ADAPTIVE TRAINING SEQUENCE FOR SYSTEMS USING TIME DIVISION MULTIPLE ACCESS



(57) Abstract: A method for controlling transmissions from a remote unit in a time division multiple access system is provided. The method includes monitoring transmissions from the remote unit at a base station, generating commands for distributing probes in at least one subsequent transmission from the remote unit based on the monitored transmissions, and transmitting the commands to the remote unit for the at least one subsequent transmission.

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Adaptive Training Sequence for Systems Using Time Division Multiple Access

Technical Field

The present invention relates generally to the field of telecommunications and, in particular, to an adaptive training sequence for systems using time division multiple access.

Background

Telecommunications systems transmit signals between user equipment, e.g., telephones, radios, and computers, over a network. Conventional telecommunications systems include, but are not limited to, the public switched telephone network (PSTN), the Internet, wireless networks, and cable television networks. These networks typically include transmission media such as coaxial cable, copper wires, optical fibers, and wireless links, e.g., radio and satellite communications.

Conventionally, transmission media carry the signals over the network in channels. In carrying signals, the channels may degrade or otherwise negatively impact the quality of the signals generated by one user for transmission to another user due to characteristics of the channel. For example, "multipath fading" is one source of degradation in signals of the channel in a telecommunications network. In wireless networks, multipath fading is often experienced due to the reception of signals that traverse different propagation paths. The multiple propagation paths are typically produced by atmospheric refraction and layering. Alternatively, the multipath signals may be produced by reflections from ground clutter near a radio receiver. Other systems also may suffer from multipath fading. For example, hybrid fiber-coax systems typically experience multipath fading due to impedance mismatches between various network components.

Time dispersion of a multipath channel is often characterized by the root mean squared (rms) time delay spread (σ_τ). This quantity is defined as the square

root of the second central moment of the power delay profile. In the frequency domain, fading is often characterized as "flat" or "frequency selective" based on the relationship between rms delay spread and the duration of the modulated digital symbol (T_{SYM}). Flat fading occurs when the rms time delay spread of the received signal is small enough to not cause significant intersymbol interference (ISI). A common relationship used in industry is that $\sigma_\tau < 0.1\ T_{SYM}$ to characterize a channel as flat fading. Conversely, a channel may be considered frequency selective if the $\sigma_\tau > 0.1\ T_{SYM}$. There is not a sharp distinction between the two types of channels as these mathematical relationships imply, but they serve as a starting point for further analysis. If a communications channel is frequency-selective, the resultant intersymbol interference produces a system bit error rate floor.

During the design of a particular network, circuits are often included in an attempt to overcome these problems to produce a signal at a receiver that fairly represents the signal generated at a transmitter. For example, an equalizer is often used to compensate for a frequency-selective channel in a digital communications system. The equalizer reduces the intersymbol interference present at its output port, thereby lowering the system bit error rate produced by such interference. In effect, the equalizer acts as an inverse filter of the communications channel.

For an equalizer to be effective, the equalizer settings, e.g., the equalizer coefficients, are selected so as to compensate for the degrading effects of the channel at the time of transmission. In many systems, the channel characteristics are generally unknown and may change over time. Adaptive equalizers are commonly used to compensate for a time varying channel transfer function. In systems that process a continuous signal, the adaptation of equalizer coefficients is well understood by those skilled in the art. However, single adaptive equalizers, when employed in Time Division Multiple Access systems, may not be effective in reducing intersymbol interference since the channel may have significantly changed since the last transmission from a particular user. In fact, if a transmission over the channel is equalized with the equalizer settings used for a prior transmission, the performance of the system may be degraded more than if no equalization were

performed at all.

For the reasons stated above, and for other reasons stated below which will become apparent to those skilled in the art upon reading and understanding the present specification, there is a need in the art for improvements in compensating for multipath fading in telecommunications systems.

SUMMARY

The above mentioned problems with telecommunications systems and other problems are addressed by embodiments of the present invention and will be understood by reading and studying the following specification. Embodiments of the present invention use adaptive training sequences or probes to allow an equalizer to compensate for time varying characteristics of a communication channel. In one embodiment, adaptive training sequences are implemented by selectively adjusting a remote unit's burst or time slot profile to contain one or more distributed intra-burst equalizer training sequences. This may be done on a burst-by-burst basis. The training sequences used in a selected burst or time slot are selected at the base station and are based on prior signals received over the channel from the remote unit. In one embodiment, the training sequences are spaced at regular intervals within the remote unit's time slot. In other embodiments, the placement of training sequences in a time slot is selected from a library of random or aperiodic patterns. By selectively adjusting the distribution of training sequences for a remote unit, channels with time varying characteristics are adequately compensated for adverse affects of multipath fading and the like.

More particularly, in one embodiment a method for controlling transmissions from a remote unit in a time division multiple access system is provided. The method includes monitoring transmissions from the remote unit at a base station, generating commands for distributing probes in at least one subsequent transmission from the remote unit based on the monitored transmissions, and transmitting the commands to the remote unit for the at least one subsequent transmission.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of an embodiment of a system that uses adaptive training sequences in time division multiple access signals in the uplink of the system according to the teachings of his invention.

Figure 2 is a block diagram of an embodiment of a burst of data for a time division multiple access channel with selectively placed intra-burst training sequences according to one embodiment of the present invention.

Figure 3 is a graph that provides an example of adaptive training sequences in a time division multiple access system according to the teachings of the present invention.

Figure 4 is an embodiment of an uplink circuit including a training sequence adaptation circuit for a base station according to the teachings of the present invention.

Figure 5 is a flow chart of an embodiment of a process for controlling the insertion of training sequences in a transmission from a remote unit for a base station equalizer according to the teachings of the present invention.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings which form a part hereof, and in which is shown by way of illustration specific illustrative embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that logical, mechanical and electrical changes may be made without departing from the spirit and scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense.

Figure 1 is a block diagram of an embodiment of a system, indicated generally at 100, that selectively inserts equalizer training sequences in time slots for remote units to compensate for time varying aspects of a communication channel. System 100 uses time division multiple access in the uplink. In one embodiment,

system 100 is a multipoint-to-point network. System 100 includes base station 102. Base station 102 is communicatively coupled to a plurality of remote units 104-1, . . ., 104-N over communication links 105-1, . . ., 105-N. Base station 102 is also coupled to core network 108 over high-speed, backhaul communications link 106. Link 106 carries communication between core network 108 via base station 102 for remote units 104-1, . . ., 104-N. In one embodiment, core network 108 comprises the Internet. In other embodiments, core network 108 comprises the Public Switched Telephone Network (PSTN), a wireless network, or any other appropriate telecommunications network.

System 100 carries signals in two directions. In the forward direction, system 100 carries signals from core network 108 to remote units 104-1, . . ., 104-N. Base station 102 multiplexes incoming backhaul data from the core network 108 to be transferred to remote units 104-1, . . ., 104-N over communication links 105-1, . . ., 105-N. The downlink media for communication links 105-1, . . ., 105-N comprises, in one embodiment, a wireless media, e.g., transmissions in the MMDS spectrum between fixed wireless units. In other embodiments, the downlink media for communication links 105-1, . . ., 105-N comprises one of coaxial cable, fiber optics, and other appropriate communications media. In one embodiment, the downlink from base station 102 uses time division multiplexing (TDM). In other embodiments, the downlink from base station 102 uses frequency division multiplexing (FDM) or other appropriate multiplexing technology.

In the reverse direction or uplink, system 100 carries signals from remote units 104-1, . . ., 104-N to base station 102 over communication links 105-1, . . ., 105-N. Base station 102 aggregates data from remote units 104-1, . . ., 104-N and transmits data over backhaul communications link 106 to core network 108. In the uplink, system 100 uses time division multiple access (TDMA) as the multiple access method. TDMA is used to share a fixed allocation of bandwidth in the frequency domain. In this access method, each user transmits over the full link bandwidth for a short duration of time, hereafter referred to as a "time slot." In one embodiment, base station 102 exercises complete control of timeslot assignment. In

other embodiments, contention algorithms are used to compete for available time slots. Further, in one embodiment timeslots have a fixed duration. In other embodiments, timeslots have a variable duration.

Base station 102 includes a training sequence adaptation circuit that instructs each remote unit 104-1, . . ., 104-N as to the appropriate number and timing of training sequences to transmit in a time slot to assure proper operation of one or more equalizers at base station 102 associated with the remote unit. In one embodiment, base station 102 includes a single equalizer and in other embodiments base station 102 includes a plurality of equalizers. Each equalizer in base station 102 is selected from linear and non-linear equalizers. In one embodiment, the nonlinear equalizers use a decision-feedback topology, although other nonlinear equalizers are used in other embodiments. If a decision-feedback equalizer is used, the feedback path is disabled when processing a training sequence from a remote unit. In this mode of operation, the equalizer is adjusted by comparing the detected symbols with a known training sequence; e.g., decision-feedback is disabled because the ideal reference symbols are known a priori. The equalizers in base station 102 each comprise one of lattice and transversal structure. Further, the equalizers in base station 102 each use one of a recursive least squares adaptation algorithm, a least mean-square adaptation algorithm, a zero forcing adaptation algorithm, a gradient recursive least squares adaptation algorithm, a fast recursive least squares adaptation algorithm, a square root recursive least squares adaptation algorithm, or other appropriate adaptation algorithm.

In one embodiment, base station 102 instructs remote units 104-1, . . ., 104-N to selectively insert training sequences or "probes" within each burst or timeslot transmission from the remote unit based on prior transmissions from the remote unit. The number, duration and spacing of probes is selectable on a per time slot basis, if needed. Further, in some embodiments, the probes are equally spaced over time within the time slot. In other embodiments, the probes are sporadically dispersed over the duration of the time slot according to a selected criteria. Advantageously, the selective insertion of probes in the bursts from remote units allows proper

operation of the base station equalizers even in light of time varying conditions in the communications channel.

Figure 2 is a block diagram that illustrates the insertion of probes in a time slot according to one embodiment of the present invention. In this embodiment, probes in a time slot are defined based on three parameters computed by the base station and communicated to the remote units:

1. <u>Training sequence offset</u>: This parameter is illustrated as time period A in Figure 2 and is measured from the end of the standard burst preamble to the beginning of the first probe. In one embodiment, this offset is set based on a sixteen-bit field with a value from 0 (disabled) to 65535 symbols. For example, a value of 10 indicates that the probe begins 10 symbols after the end of the standard burst preamble.

2. <u>Training sequence interval</u>: This parameter is illustrated as time period B in Figure 2 and is measured from the beginning of a first probe to the beginning of a next sequential probe. In one embodiment, this interval is set based on a sixteen-bit field with a value from 0 (disabled) to 65535 symbols.

3. <u>Training sequence length</u>: This parameter is illustrated as time period C in Figure 2 and is measured from the beginning to the end of a given probe. In one embodiment, this length is set based on an eight-bit field with a value from 0 (disabled) to 255 symbols.

Base station 102 includes circuitry that calculates appropriate values for these three parameters for each remote unit 104-1, . . ., 104-N. In one embodiment, the values are calculated for each burst for a particular remote unit to provide sufficient probes in the next burst such that the equalizer overcomes problems due to time-varying characteristics of the channel. In other embodiments, the values for the parameters for each remote unit 104-1, . . ., 104-N are calculated at other appropriate times.

The examples of the parameters and field sizes for these parameters are provided by way of illustration and not by way of limitation. Other parameters and

other field sizes are used in other embodiments. In each case, the parameters and field sizes are chosen to allow the base station to adequately define probes to reduce problems associated with time varying channel characteristics and to assure proper operation of equalizer circuits for each remote unit 104-1, . . ., 104-N at base station 102.

Figure 3 is a graph that provides an example of adaptive training sequences in a time division multiple access system according to the teachings of the present invention. In this example, remote unit 104-1 transmits during time slot 1. Initially, the base station instructs remote unit 104-1 to transmit with no distributed probes. The only training sequence used in the first transmission from remote unit 104-1 immediately follows the standard burst preamble. During the transmission in this first time slot, the base station detects a significant packet error rate. Due to this detected packet error rate, the base station instructs the remote user to use distributed probes in its next time slot. The base station calculates appropriate offset and interval parameters to produce distributed probes in the next successive time slot for remote unit 104-1. The probes allow the equalizer at the base station to track channel variations during the transmission from remote unit 104-1.

Figure 3 also illustrates transmissions from three other remote units. The transmission from remote unit 104-N contains a large number of probes to cope with a rapidly changing channel based on prior transmissions received at the base station from remote unit 104-N. The transmission from remote unit 104-2 illustrates that the base station determined that the link delay and time variation for this remote unit were not sufficient to require a high rate of training sequences. Thus, a single, short training sequence is inserted in the time slot by remote unit 104-2. The transmission from remote unit 104-3 contains a large number of probes of short duration. Based on prior transmissions, the base station determined that a large number of probes were necessary to track channel variations for remote unit 104-3. Thus, Figure 3 illustrates that each remote unit is controlled separately by the base station to insert a sufficient number of intra-burst probes to allow an associated equalizer to compensate for time varying characteristics of the channel. Further, Figure 3

illustrates that the base station can change the number of probes for a particular remote unit on a per time slot basis.

Figure 4 is an embodiment of an uplink circuit, indicated generally and 400, including training sequence adaptation circuit 402 for a base station according to the teachings of the present invention.

Uplink circuit 400 processes signals from a remote unit. Uplink circuit 400 receives signals from a remote unit at signal conditioning circuit 404. In one embodiment, signal conditioning circuit 404 comprises an automatic gain control circuit and other appropriate circuits for conditioning the signal from the remote unit.

Signal conditioning circuit 404 is coupled to equalizer 406. In one embodiment, equalizer 406 is a single equalizer. In other embodiments, equalizer 406 is a plurality of equalizers. Equalizer 406 is selected from linear and non-linear equalizers. In one embodiment, equalizer 406 uses a decision-feedback topology. If a decision-feedback equalizer is used, the feedback path is disabled when processing a training sequence from a remote unit. In this mode of operation, the equalizer is adjusted by comparing the detected symbols with a known training sequence; e.g., decision-feedback is disabled because the ideal reference symbols are known a priori. Equalizer 406 comprises one of a lattice structure and a transversal structure. Further, equalizer 406 uses one of a recursive least squares adaptation algorithm, a least mean-square adaptation algorithm, a zero forcing adaptation algorithm, a gradient recursive least squares adaptation algorithm, a fast recursive least squares adaptation algorithm and a square root recursive least squares adaptation algorithm.

Uplink circuit 400 further includes error correction decoder 408 and packet decoder 410 to correct for errors in signals from the remote unit. Error correction decoder 408 is coupled to an output of equalizer 406 and provides an output to packet decoder 410. Packet decoder 410 provides an output to follow-on receiver processing circuit 412.

Uplink circuit 400 further includes training sequence adaptation circuit 402. Adaptation circuit 402 includes input 414 and output 416. Input 414 is coupled to monitor the quality of signals processed by equalizer circuit 406, error correction decoder 408, and packet decoder 410. In one embodiment, input 414 is coupled to receive a measure of an error rate of uplink circuit 400. For example, input 414 is coupled to at least one of equalizer 406, error correction decoder 408, and packet decoder 410. Equalizer 406 provides a mean-squared-error (MSE) signal to input 414 as a measure of the error in equalizing signals from remote unit. Error correction decoder 408, e.g., a forward error correction decoder, provides a codeword error rate (CER) to input 414 as a measure of the error in signals from the remote unit. Further, packet decoder 410 provides a packet error rate (PER) to input 414 as a measure of the error in packets received from the remote unit.

In Figure 4, input 414 is illustrated as receiving signals from each of equalizer 406, error correction decoder 408, and packet decoder 410. However, it is understood, that input 414, in other embodiments, is coupled to any one or more of equalizer 406, error correction decoder 408, packet decoder 410, or other appropriate circuitry in uplink circuit 400.

Adaptation circuit 402 also includes command generation module 418. Command generation module 418 is coupled between input 414 and output 416. In one embodiment, command generation module 418 generates commands for a remote unit to establish values for parameters that control the selective insertion of training sequences in at least one subsequent time slot. For example, command generation module 418, in one embodiment, generates values for at least one of a training sequence offset, a training sequence interval, and a training sequence length parameter to control the insertion of training sequences. One embodiment of a process for generating commands for the remote unit is shown and described with respect to Figure 5 below.

In operation, uplink circuit 400 processes signals from a remote unit and generates commands for selectively inserting training sequences in at least one subsequent transmission from the remote unit. Signals from the remote unit are

initially conditioned in signal conditioning circuit 404. Further, signals from signal conditioning circuit 404 are equalized by equalizer 406, corrected for error by error correction decoder 408, and corrected for packet errors by packet decoder 410. At least one of equalizer 406, error correction decoder 408, and packet decoder 410 provides a measure of the error rate in signals from the remote unit to training sequence adaptation circuit 402. Adaptation circuit 402 uses this information to generate commands to control the selective insertion of training sequences in at least one subsequent transmission from the remote unit.

Figure 5 is a flow chart of an embodiment of a process for controlling the insertion of training sequences in a transmission from a remote unit for a base station equalizer according to the teachings of the present invention. The method begins at block 500. At block 502, the method monitors an error rate in signals from a remote unit. In one embodiment, the method monitors an error rate based on a signal from an equalizer. In another embodiment, the method monitors an error rate based on a signal from an error correction decoder. In a further embodiment, the method monitors an error rate based on a signal from a packet decoder. In other embodiments, the method monitors an error rate based on any one or more of signals from an equalizer, an error correction decoder, and a packet decoder.

Based on the monitored error rate, the method generates commands to control the selective insertion of training sequences in a subsequent transmission from the remote unit. At block 504, the method determines whether a change in the error rate exceeds the threshold. If not, the method returns to block 502 and continues to monitor the error rate. If, however, the error rate exceeds the threshold, the method proceeds to block 506 and determines whether the error rate is increasing. If so, the method generates commands to increase the number of probes in at least one subsequent transmission from the remote unit at block 508. If, however, the error rate is not increasing, then the method generates commands to instruct the remote unit to decrease the number of probes in at least one subsequent transmission at block 510. The method returns from either block 508 or block 510 to block 502 to continue to monitor the error rate.

Conclusion

Embodiments of the present invention have been described. The embodiments provide compensation for time varying characteristics of a time division multiple access communications channel by selectively controlling the insertion of probes or training sequences in transmissions from the remote unit. Essentially, signals from the remote unit are monitored at the base station, and, based on the monitored signals, commands are generated to adjust, as necessary, the insertion of probes in subsequent transmissions from the remote unit. When the signals from the remote unit begin to degrade due to time varying channel conditions, additional probes can be inserted into subsequent transmissions to allow the equalizer to compensate for these changing characteristics more readily. Thus, channels with time varying characteristics are adequately compensated for adverse affects of multipath fading and the like.

Advantageously, the embodiments described overcome problems with equalizer mismatch due to significant changes in a channel since a prior transmission. Further, the embodiments provide the advantage of reduced overhead in transmissions from the remote unit when channel conditions improve. By using training sequences distributed in the transmission from the remote unit, the equalizer advantageously is allowed to adapt more rapidly in a dynamic channel. Further, since the processing is performed at the base station, pre-equalization at the remote units is not required.

Although specific embodiments have been illustrated and described in this specification, it will be appreciated by those of ordinary skill in the art that any arrangement that is calculated to achieve the same purpose may be substituted for the specific embodiment shown. This application is intended to cover any adaptations or variations of the present invention. For example, measures of the quality of signals from a remote unit other than signals from an equalizer, an error correction decoder and a packet decoder can be used. Further, the command generation module can be implemented in hardware, software, or a combination of both. The selective placement of probes within a time slot is not limited to use of

the three parameters defined with respect to Figure 2 above. Other parameters can be used. Further, the position of probes within a time slot can be controlled based on a look-up table or any other appropriate mechanism for distributing the probes in the time slot window to reduce problems with time varying channels.

What is claimed is:

1. A method for controlling transmissions from a remote unit in a time division multiple access system, the method comprising:

monitoring transmissions from the remote unit at a base station;

generating commands for distributing probes in at least one subsequent transmission from the remote unit based on the monitored transmissions; and

transmitting the commands to the remote unit for the at least one subsequent transmission.

2. The method of claim 1, wherein monitoring transmissions from the remote unit comprises monitoring a mean-squared-error signal from an equalizer.

3. The method of claim 1, wherein monitoring transmissions from the remote unit comprises monitoring a codeword error rate from an error correction decoder.

4. The method of claim 1,wherein monitoring transmissions from the remote unit comprises monitoring a packet error rate of a packet decoder.

5. The method of claim 1, wherein establishing commands comprises determining the values for at least one of a training sequence offset, a training sequence interval, and a training sequence length.

6. The method of claim 1, wherein establishing commands comprises establishing values for parameters based on at least one of a mean-squared-error signal from an equalizer, a codeword error rate from an error correction decoder, and a packet error rate from a packet decoder.

7. The method of claim 1, wherein establishing commands comprises increasing the number of training sequences in a time slot of the at least one subsequent transmission for the remote unit when the monitored transmissions

exhibit a sufficiently large increase in error rate.

8. An uplink circuit for a base station in a telecommunications system using time division multiple access, the uplink circuit comprising:

a signal conditioning circuit having an input adapted to receive signals from a remote unit;

an equalizer, responsive to the signal conditioning circuit, that is adapted to equalize signals from the remote unit;

an error correction decoder, responsive to the equalizer, that is adapted to correct errors in signals from the remote unit;

a packet decoder, responsive to the error correction decoder, that is adapted to correct errors in packets from the remote unit; and

a training sequence adaptation circuit, responsive to at least one of the equalizer, the error correction decoder and the packet decoder, that is adapted to generate commands for the remote unit to selectively insert training sequences in at least one subsequent time slot for the remote unit.

9. The uplink circuit of claim 8, wherein the training sequence adaptation circuit generates commands based on a codeword error rate from the error correction decoder.

10. The uplink circuit of claim 8, wherein the training sequence adaptation circuit generates commands based on a mean-squared-error from the equalizer.

11. The uplink circuit of claim 8, wherein the training sequence adaptation circuit generates commands based on a packet error rate from the packet decoder.

12. The uplink circuit of claim 8, wherein the equalizer comprises one of a linear equalizer and a nonlinear equalizer.

13. An uplink circuit for a base station in a telecommunications system using time division multiple access, the uplink circuit comprising:

an equalizer that is adapted to equalize signals from the remote unit;

an error correction decoder, responsive to the equalizer, that is adapted to correct errors in signals from remote unit; and

a training sequence adaptation circuit, responsive to the error correction decoder, that is adapted to generate commands for the remote unit to selectively insert training sequences in at least one subsequent time slot for the remote unit.

14. The uplink circuit of claim 13, wherein the error correction decoder comprises a forward error correction decoder that generates a codeword error rate signal provided to the training sequence adaptation circuit.

15. The uplink circuit of claim 13, wherein the equalizer comprises one of a linear equalizer and a nonlinear equalizer.

16. A training sequence adaptation circuit, comprising:

an input adapted to receive at least one measure of an error rate for a communication channel for a remote unit;

a command generation module, coupled to the input, that generates commands for the remote unit based on the at least one measure to selectively insert training sequences in at least one subsequent time slot for the remote unit; and

an output, responsive to the command generation module, that provides the commands for transmission to the remote unit.

17. The adaptation circuit of claim 16, wherein the input is adapted to receive a measure of an error rate from an equalizer.

18. The adaptation circuit of claim 16, wherein the input is adapted to receive a measure of an error rate from a forward error correction decoder.

19. The adaptation circuit of claim 16, wherein the input is adapted to receive a measure of an error rate from a packet decoder.

20. The adaptation circuit of claim 16, wherein the command generation module generates commands for the remote unit that include values for at least one of a training sequence offset, a training sequence interval, and a training sequence length.

21. The adaptation circuit of claim 16, wherein the command generation module generates commands to increase the number of training sequences in a time slot when the at least one measure of an error rate indicates that the error rate is increasing.

22. A method for controlling transmissions from a remote unit in a time division multiple access system, the method comprising:

receiving transmissions from a remote unit at a base station;

equalizing the received transmissions;

correcting errors in the received transmissions;

monitoring the correcting errors;

establishing commands for inserting probes in at least one subsequent transmission from the remote unit based on monitoring the correcting errors; and

transmitting the commands to the remote unit for the at least one subsequent transmission.

23. The method of claim 22, wherein monitoring the correcting errors comprises monitoring a codeword error signal from the forward error correction decoder.

24. The method of claim 22, wherein establishing commands for inserting probes comprises determining values for at least one of a training sequence offset, a training sequence interval, and a training sequence length.

25. The method of claim 22, wherein establishing commands comprises increasing the number of probes in a time slot of the at least one subsequent transmission for the remote unit when the monitoring correcting errors exhibits a sufficiently large increase in error rate.

26. A telecommunications system, comprising:

at least one base station adapted to provide a connection to a core network;

the base station including a circuit that receives signals from the core network and provides the signals to a plurality of remote units over at least one communication channel;

the base station further including a receiver that receives time division multiple access signals from a plurality of remote units over at least one communication channel; and

wherein the base station includes a training sequence adaptation circuit, the training sequence adaptation circuit including:

an input adapted to receive at least one measure of an error rate for a communication channel for a remote unit;

a command generation module, coupled to the input, that generates commands for the remote unit based on the at least one measure to selectively insert training sequences in at least one subsequent time slot for the remote unit; and

an output, responsive to the command generation module, that provides the commands for transmission to the remote unit.

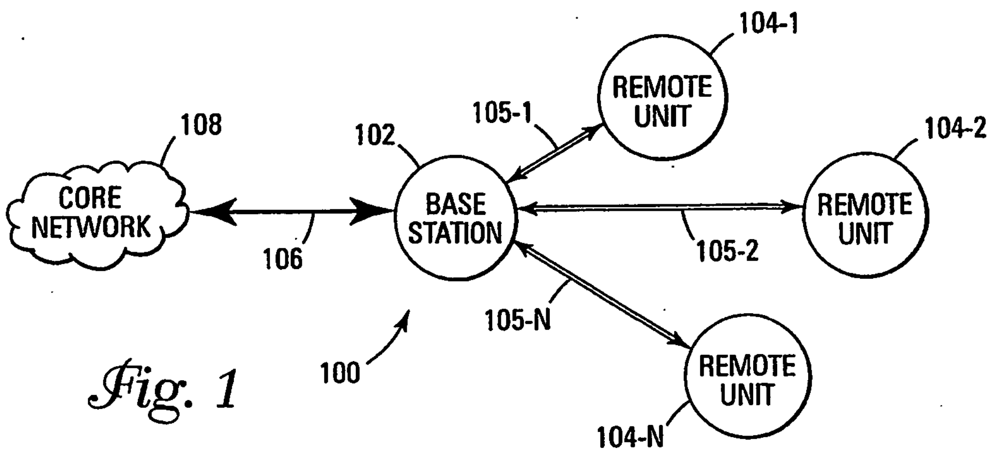
27. The system of claim 26, wherein the input is adapted to receive a measure of an error rate from an equalizer.

28. The system of claim 26, wherein the input is adapted to receive a measure of an error rate from a forward error correction decoder.

29. The system of claim 26, wherein the input is adapted to receive a measure of an error rate from a packet decoder.

30. The system of claim 26, wherein the command generation module generates commands for the remote unit that include values for at least one of a training sequence offset, a training sequence interval, and a training sequence length.

31. The system of claim 26, wherein the command generation module generates commands to increase the number of training sequences in a time slot when the at least one measure of an error rate indicates that the error rate is increasing.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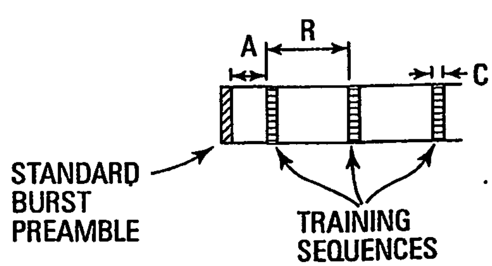
REMOTE UNIT
108
102
105-1
104-2
CORE NETWORK
BASE STATION
REMOTE UNIT
106
105-2
105-N
100
REMOTE UNIT
104-N

Fig. 1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R
C
STANDARD BURST PREAMBLE
TRAINING SEQUENCES

Fig. 2

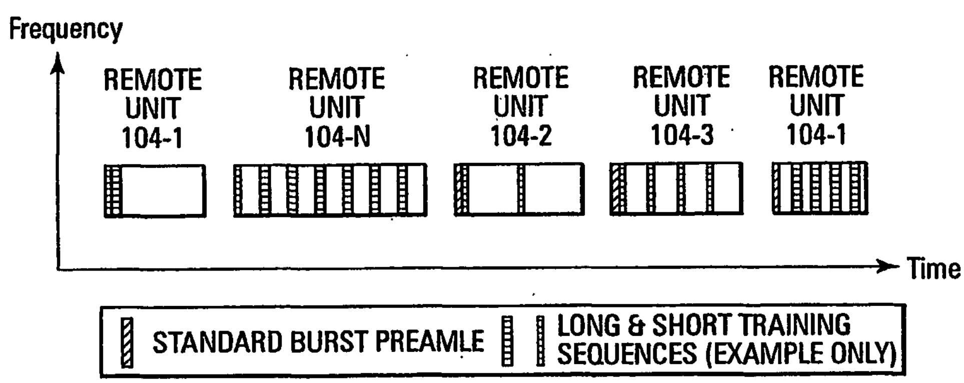
Frequency
REMOTE UNIT 104-1
REMOTE UNIT 104-N
REMOTE UNIT 104-2
REMOTE UNIT 104-3
REMOTE UNIT 104-1
Time
STANDARD BURST PREAMLE
LONG & SHORT TRAINING SEQUENCES (EXAMPLE ONLY)

Fig. 3

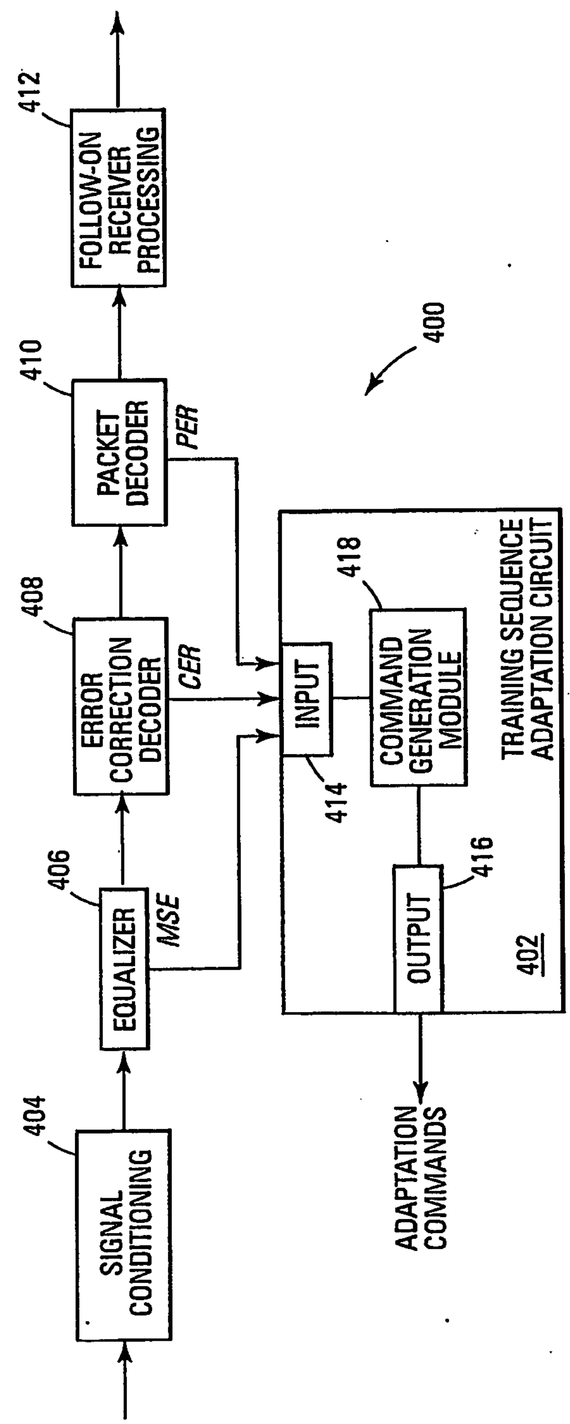
SIGNAL CONDITIONING
404
EQUALIZER
406
MSE
ERROR CORRECTION DECODER
408
CER
PACKET DECODER
410
PER
FOLLOW-ON RECEIVER PROCESSING
412
400
INPUT
414
COMMAND GENERATION MODULE
418
OUTPUT
416
402
TRAINING SEQUENCE ADAPTATION CIRCUIT
ADAPTATION COMMANDS

Fig. 4

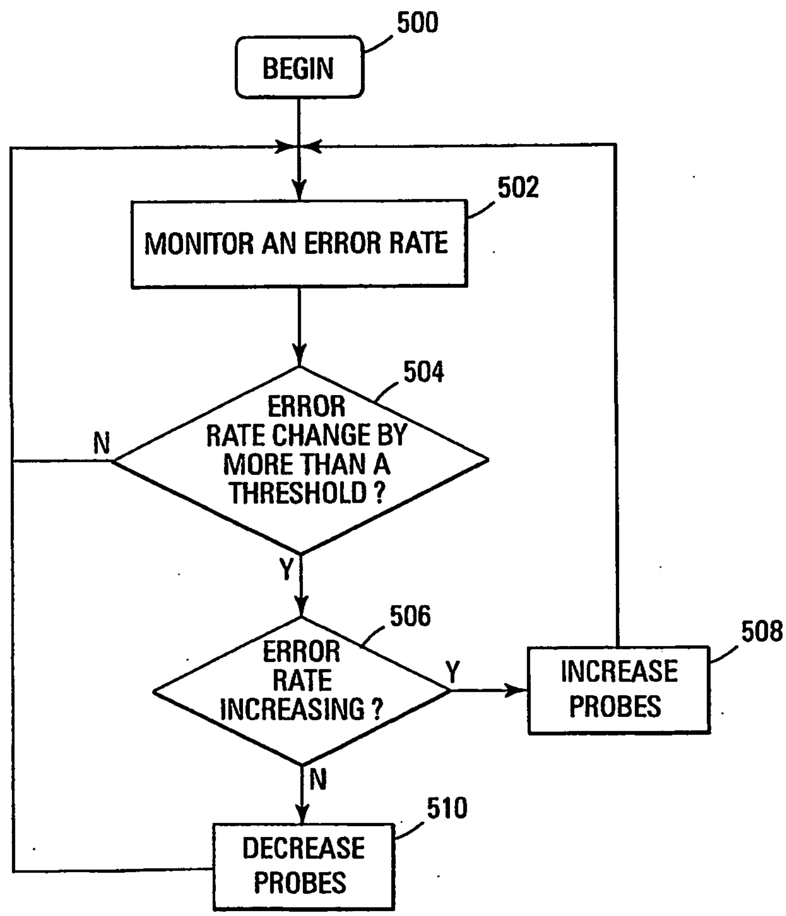
500
BEGIN
502
MONITOR AN ERROR RATE
504
ERROR RATE CHANGE BY MORE THAN A THRESHOLD ?
N
Y
506
ERROR RATE INCREASING ?
Y
508
INCREASE PROBES
N
510
DECREASE PROBES

Fig. 5